Check List
the journal of biodiversity data

NOTES ON GEOGRAPHIC DISTRIBUTION

Check List 12(6): 2023, 27 December 2016 doi: https://doi.org/10.15560/12.6.2023
ISSN 1809-127X © 2016 Check List and Authors

Sympatric occurrence of two species of *Pseudopaludicola* (Anura: Leptodactylidae) and first record of *Pseudopaludicola jaredi* Andrade, Magalhães, Nunes-de-Almeida, Veiga-Menoncello, Santana, Garda, Loebmann, Recco-Pimentel, Giaretta & Toledo, 2016 in the state of Maranhão, northeastern Brazil

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Abstract: Here, we document the sympatric occurrence of *Pseudopaludicola canga* and *P. jaredi*. We also provide the first record of *P. jaredi* in the state of Maranhão, northeastern Brazil, expanding this species' distribution by about 610 km southwestward from Serra das Flores, municipality of Viçosa do Ceará, state of Ceará. Furthermore, we fill the gap in the geographic distribution range of *P. canga* in the state of Maranhão, extending the distribution of this species by about 530 km southwestward from the municipality of Barreirinhas.

Key words: Leiuperinae; Parque Estadual do Mirador; Cerrado; geographic distribution

The genus *Pseudopaludicola* Miranda-Ribeiro (1926) is represented by small swamp frogs, in which snout-vent lengths generally do not exceed 20 mm (Lobo 1992; Kehr & Schaefer 2005; Toledo et al. 2010; Fávero et al. 2011). Allocated to the subfamily Leiuperinae (Pyron & Wiens 2011; Veiga-Menoncello et al. 2014), the genus has 21 currently recognized species (Frost 2016) that are widely distributed throughout South America, from northern Colombia to Argentina (Lobo 1992; Cardozo & Suarez 2012; Frost 2016). Among these species, five belong to the *P. pusilla* group (Pansonato et al. 2016): *P. boliviana* Parker, 1927, *P. ceratophryes* Rivero & Serna, 1985, *P. llanera* Lynch, 1989, *P. motorzinho* Pansonato, Veiga-Menoncello, Mudrek, Jansen, Recco-Pimentel, Martins & Strüssmann, 2016 and *P. pusilla* (Ruthven, 1916). The remaining species are not assigned to any species group (Veiga-Menoncello et al. 2014; Cardozo et al. 2016): *P. ameghini* (Cope, 1887), *P. atragula* Pansonato, Mudrek, Veiga-Menoncello, Rossa-Feres, Martins & Strüssmann, 2014, *P. canga* Giaretta & Kokubum, 2003, *P. facureae* Andrade & Carvalho, 2013, *P. falcipes* (Hensel, 1867), *P. giarettai* Carvalho, 2012, *P. hyleaustralis* Pansonato, Morais, Ávila, Kawashita-Ribeiro, Strussmann & Martins, 2012, *P. ibisoroca* Pansonato, Veiga-Menoncello, Mudrek, Jansen, Recco-Pimentel, Martins & Strüssmann, 2016, *P. jaredi* Andrade, Magalhães, Nunes-de-Almeida, Veiga-Menoncello, Santana, Garda, Loebmann, Recco-Pimentel, Giaretta & Toledo, 2016, *P. mineira* Lobo, 1994, *P. murundu* Toledo, Siqueira, Duarte, Veiga-Menoncello, Recco-Pimentel & Haddad, 2010, *P. mystacalis* (Cope, 1887), *P. parnaiba* Roberto, Cardozo & Ávila, 2013, *P. pocoto* Magalhães, Loebmann, Kokubum, Haddad & Garda, 2014, *P. saltica* (Cope, 1887), and *P. ternetzi* Miranda-Ribeiro, 1937.

The species of *Pseudopaludicola* can be found calling preferentially during the day (except for *P. pocoto* and *P. jaredi* that call preferentially at night [Magalhães et al. 2014; Andrade et al. 2016]), in swampy areas of open formations or in the vicinities of tropical forests and dry forests (Lobo 1992; Pansonato et al. 2012, 2013; Magalhães et

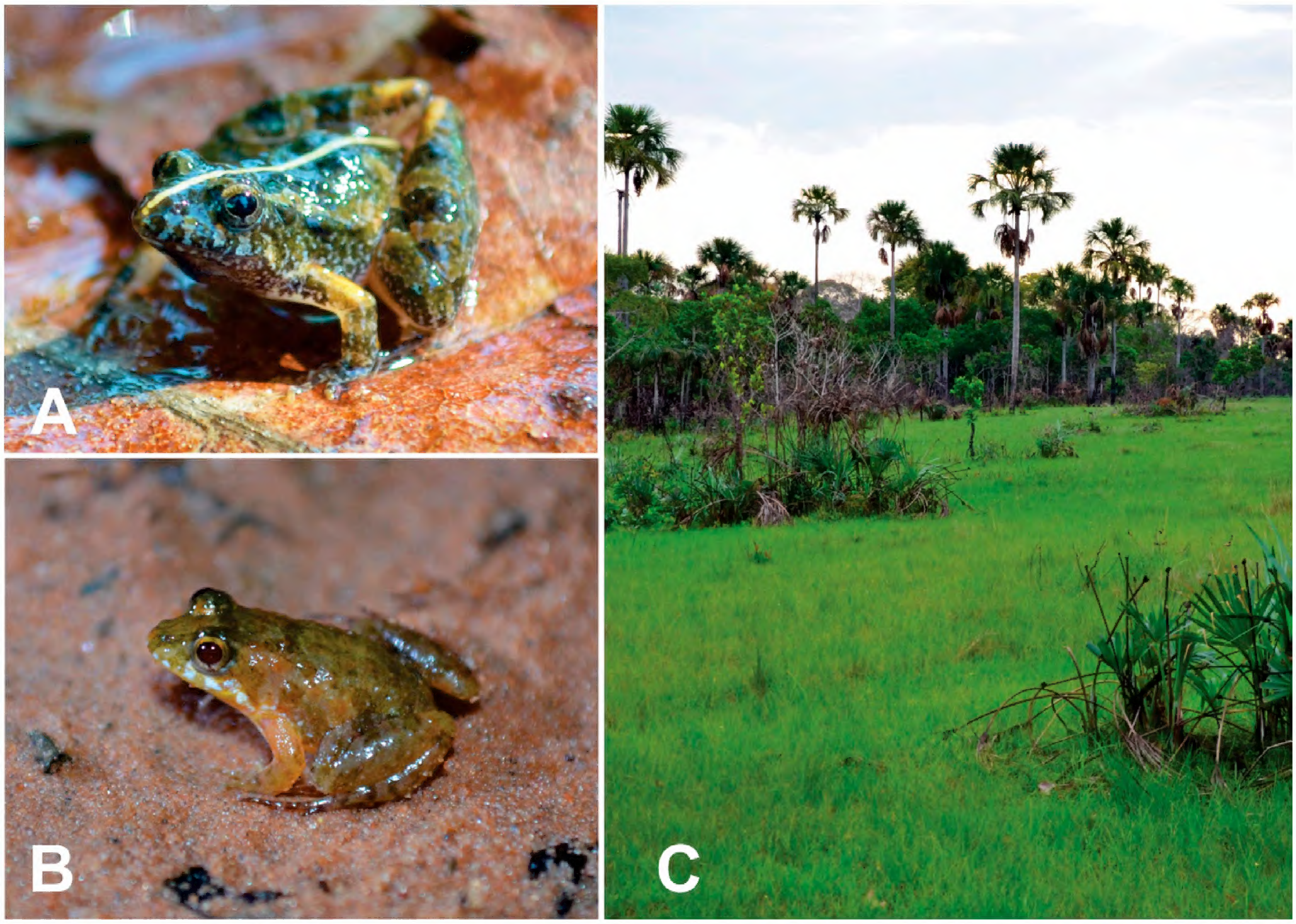

Figure 1. Species of *Pseudopaludicola* sympatrically registered in the Parque Estadual do Mirador, southern Maranhão state, Brazil. **A**. *Pseudopaludicola jaredi* (CZDP (L1) 0460; SVL = 15.9 mm). **B**. *Pseudopaludicola canga* (CZDP (L1) 0461; SVL = 12.3 mm). **C**. Flooded swamp near the banks of the Itapecuru River where the individuals was collected. Photos: Etielle Andrade.

al. 2014). The large number of cryptic species along with the conservative morphology of the genus *Pseudopaludicola* makes difficult the accurate taxonomic identification based exclusively on morphological/morphometric features (Veiga-Menoncello et al. 2014; Carvalho et al. 2015a; Andrade et al. 2016). This leads to an underestimation of the true diversity within the genus (Veiga-Menoncello et al. 2014), and makes it difficult to determine the real geographic distributions of the species.

Five species are found in northeastern Brazil (*P. canga*, *P. jaredi*, *P. mystacalis*, *P. parnaiba* and *P. pocoto*). Of these species, some are commonly found in sympatry, such as *P. pocoto* and *P. mystacalis* in areas of Caatinga and *P. jaredi* and *P. mystacalis* in ecotonal areas of Caatinga and Atlantic Forest (Loebmann & Haddad 2010; Magalhães et al. 2014; Andrade et al. 2016). However, the sympatric occurrence of *P. canga* and *P. jaredi* in this region has not been recorded. *Pseudopaludicola canga*, a species poorly known and often confused with other taxa (Cardozo & Soarez 2012), was long considered endemic to Serra dos Carajás, in the municipality of Marabá, state of Pará (Giaretta & Kokubum 2003). Currently it is known to occur in the state of Pará (Conceição do Araguaia, Curionópolis, and São Geraldo do Araguaia) and Tocantins (Palmas and Mateiros), as well as in isolated populations in the northern Maranhão (Barreirinhas municipality) (Duarte et al. 2010; Pansonato et al. 2012; Oliveira et al. 2013; Carvalho et al. 2015b). On the other hand, *P. jared* has only been recorded from the municipalities of Viçosa do Ceará, state of Ceará, and Nísia Floresta, state of Rio Grande do Norte, both in the Northeast Region of Brazil, where it inhabits in flooded grasslands and patches of high Cerrado (Loebmann & Haddad 2010; Andrade et al. 2016). Thus, we provide a record of the sympatric occurrence of *P. canga* and *P. jaredi*, and we document the first record of *P. jaredi* in the state of Maranhão, northeastern Brazil. Additionally, we present a range extension of *P. canga* to the state of Maranhão, filling the gap in its geographic distribution.

The specimens were collected in December 2014 and February 2015 at Parque Estadual do Mirador (PEM; –6.791167, –45.473639; datum WGS84), in southern Maranhão state, Northeast Region, Brazil. Parque Estadual do Mirador, located between Mirador, Formosa da Serra Negra, and Fernando Falcão municipalities, presents a sub-humid tropical climate with temperatures ranging from 19°C to 33°C, and vegetation typical of the Cerrado biome (Alcântara 2004). The species were found calling

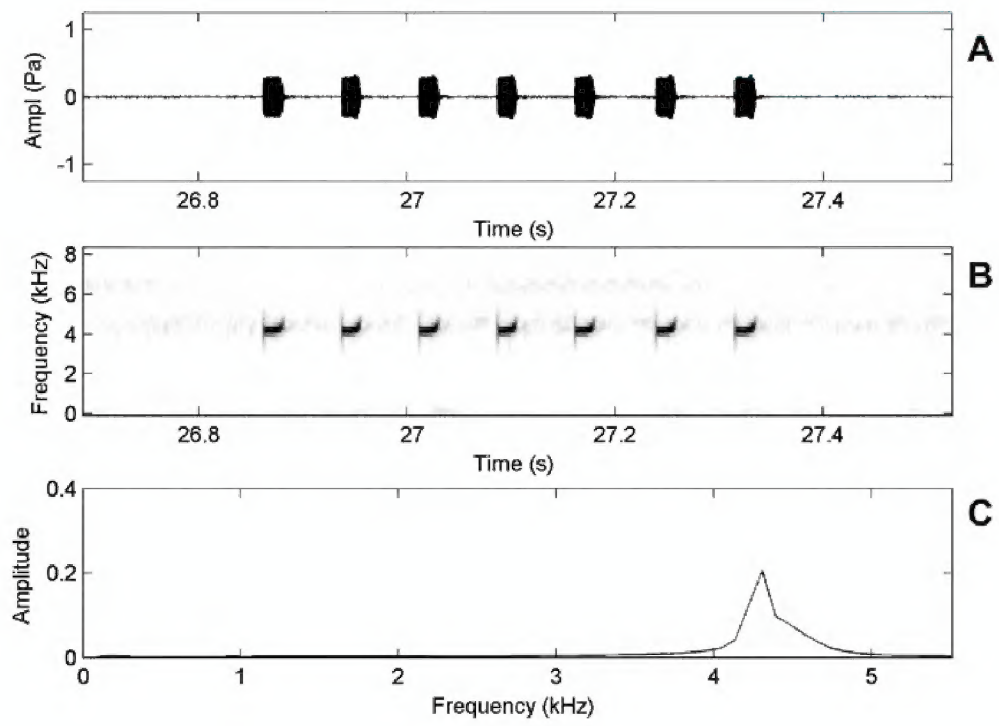

Figure 2. Advertisement call of *Pseudopaludicola canga* (CZDP (L1) 0461; Figure 1B) from Parque Estadual do Mirador, Maranhão, northeastern Brazil. **A.** Waveform. **B.** Spectrogram. **C.** Power spectrum.

in syntopy at dusk (around 18:00–18:30 h) in a flooded field covered by emergent vegetation near the banks of the Itapecuru River.

Several individuals of *P. canga* (> 30 individuals) were found calling continuously in chorus, while only a few individuals of *P. jaredi* (< 10 individuals) were observed calling. Using a digital recorder (Marantz PMD660), coupled to a directional microphone (Sennheiser Me66/K6), we recorded the advertisement call of an adult male of *P. canga* to assure the correct species' identification. Recordings were sampled at a rate of 44.1 kHz and a 16-bit resolution and analyzed with the software SoundRuler, version 0.9.6 (Bee 2004; Gridi-Papp 2004). The identification of *P. canga* was based on morphological characters (Giaretta & Kokubum 2003; Cardozo & Suarez 2012) and acoustic parameters (Carvalho et al. 2015a). Due to low number of males sporadically vocalizing, it was not possible to record the calls *P. jaredi*. Its identification was based on geographic distribution and presence of diagnostic characteristics proposed by Andrade et al. (2016). Specimens were collected under permit granted by Secretaria de Estado do Meio Ambiente e Recursos Naturais do Maranhão (SEMA-MA #008/2013) and deposited in the Coleção Zoológica Delta do Parnaíba-CZDP, Universidade Federal do Piauí-UFPI, Campus de Parnaíba-PI: *P. jaredi*: CZDP(L1) 0459 and CZDP(L1) 0460; *P. canga*: CZDP(L1) 0461 and CZDP(L1) 0462.

The individuals of *P. canga* were diagnosed by their dorsal surface smooth with the presence of an X-shaped glandular fold in the interscapular region and transversal fold across the chest. They are gray-green with darker spots on the dorsum, transverse bands on the surface of the thigh, shank and foot, upper lip with 3 or 4 white blotches, white belly and yellowish vocal sac. *Pseudopaludicola canga* recorded here has a trilled advertisement call composed by 4–10 notes pulsed with dominant frequency located in the second harmonic and varying from 4220–4737 Hz (mean 4471 Hz; SD = 160.9), emitted at rates of 3–9 notes/s (mean 5.5; SD = 2.2). Call duration varies from 635.9–731.9 ms (mean 686.8 ms; SD = 45.3) and call intervals from 291.4–1151.7 ms (mean 680.8 ms; SD = 357.7). Note duration lasts from 20.9–26.7 ms (mean 23.9; SD = 1.4), and note interval from 51.8–64.4 ms (mean 55.9; SD = 4.2). Bioacoustic data presented here (Figure 2) were similar to those reported by Carvalho et al. (2015a) for the populations of *P. canga* recorded in the municipality of Palmas, Tocantins state. Roberto et al. (2013) described in the municipality of Ribeiro Gonçalves, Piauí state, located about 100 km of the Parque Estadual do Mirador, a species of *Pseudopaludicola* with trilled advertisement call that likely resembles that of *P. canga*. However, despite the proximity between the PEM and type locality of *P. parnaiba* and that both species are phenotypically indistinguishable (Carvalho et al. 2015b), the call structure provided here (observed in the oscillogram of the Figure 2) confirms the identification of *P. canga*, as observed by Pansonato et al. (2012) and Carvalho et al. (2015b).

The specimens of *P. jaredi* presented here were treated initially as *P.* aff. *murundu* due to its long hindlimbs, with tibio-tarsal articulation reaching beyond the tip of the snout (remarkable characters of the *P. saltica* group) and by presence dark vocal sac. However, the presence of a yellow vertebral line and spots with the same colors on the upper arms and shanks (Figure 1) distinguished the population found in the state of Maranhão from the populations of *P. murundu* in southeastern Brazil. Furthermore, Andrade et al. (2016) described a new species of *Pseudopaludicola* closely related to species of *P. saltica* group and with great similarity to the species of this study. After detailed analysis, the species was confirmed as *P. jaredi* from their diagnostic characteristics and geographic distribution data. Our identification was subsequently confirmed by a specialist (Felipe Silva de Andrade). *Pseudopaludicola jaredi* is considered a sister species of *P. saltica* and *P. murundu* within the *P. saltica* group (Andrade et al. 2016), differing from *P. saltica* by presenting dark vocal sac with dark longitudinal folds and larger and clearer nuptial pads in adult males (Toledo et al. 2010). Additionally, *P. jaredi* differs from *P. murundu* by having the shank length greater and head wider, internarial and eye–snout distances wider, and a vertebral line present and spots with the same colors on the upper arms and shanks (Andrade et al. 2016).

We present here the sympatric occurrence of *P. canga* and *P. jaredi* in a flooded field covered by emergent vegetation in southern Maranhão state. Despite the cryptic pattern (Pansonato et al. 2012; Carvalho et al. 2015a, 2015b), sympatric occurrence is commonly observed among species of the genus *Pseudopaludicola* (Giaretta & Facure 2009; Loebmann & Haddad 2010; Magalhães et al. 2014; Andrade et al. 2016). This indicates that the species differ minimally in how they use natural resources and breeding sites, and the advertisement call is one of the main pre-zygotic barriers to reproductive isolation between them (Loebmann & Haddad 2010; Pansonato et al. 2012; Andrade & Carvalho 2013; Magalhães et al. 2014; Carvalho et al. 2015a, 2015b).

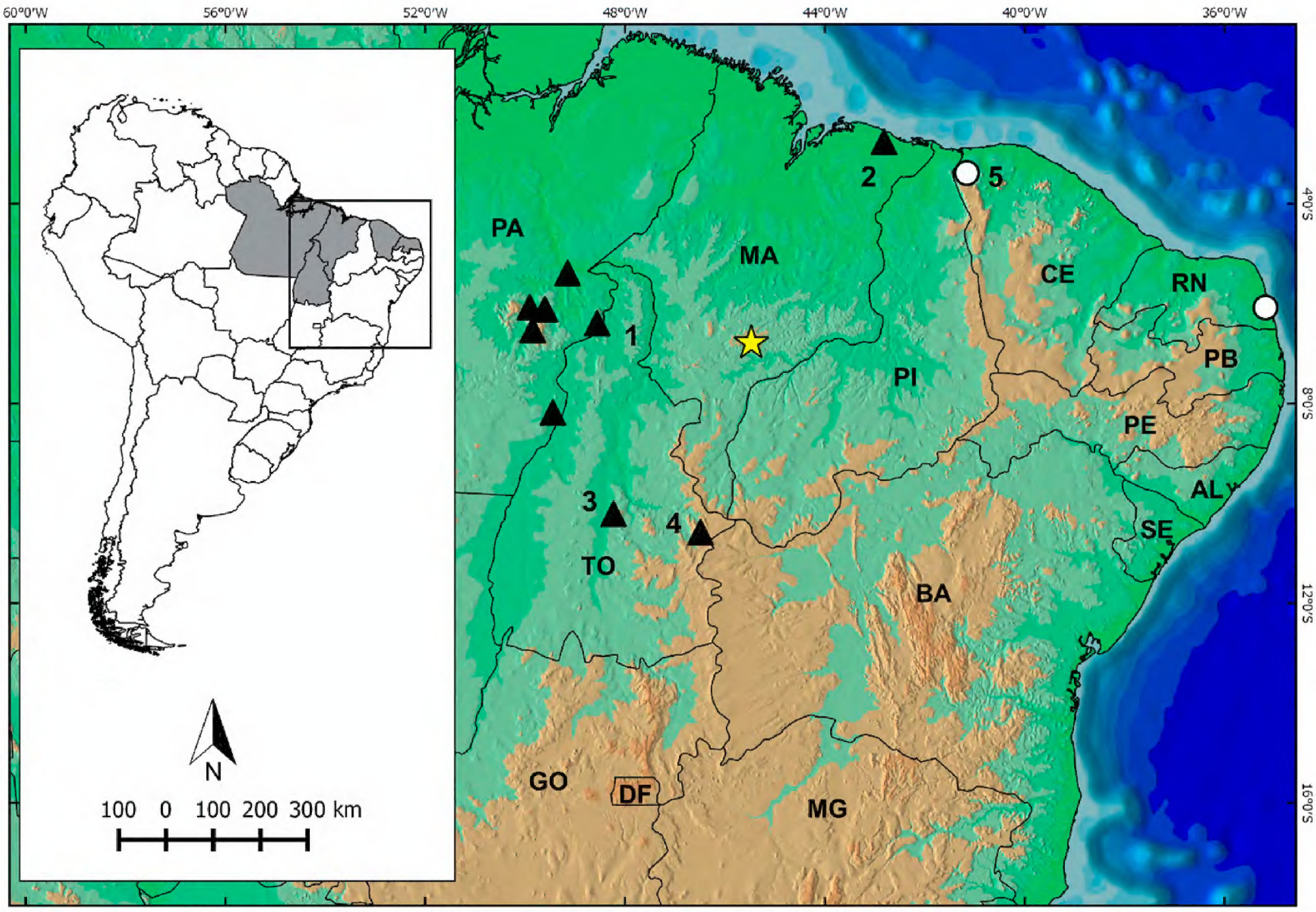

Figure 3. Geographic distribution of *Pseudopaludicola canga* and *Pseudopaludicola jaredi* with the new record (yellow star) for the Parque Estadual do Mirador, state of Maranhão, northeastern Brazil. Black triangles represent literature records of *P. canga*. White circles represent literature records of *P. jaredi*. The number represent the nearest municipalities of park where the species were recorded: (1) São Geraldo do Araguaia, state of Pará; (2) Barreirinhas, state of Maranhão; (3) Mateiros, state of Tocantins; (4) Jalapão, state of Tocantins; (5)Viçosa do Ceará, state of Ceará.

With this, we fill the gap in the geographic distribution range of *P. canga* in the state (Figure 3), extending this species' distribution about 340 km eastward from the municipality of São Geraldo do Araguaia (Oliveira et al. 2013), 430 km northward from Mateiros (Carvalho et al. 2015b), and about 530 km southwestward from Barreirinhas (Pansonato et al. 2012). The presence of *P. canga* in the southern Maranhão suggests that this species has wider distribution than previously thought. The information presented here adds to the knowledge of this species' real distribution, and consequently, to its conservation status.

Furthermore, we present the first record of *P. jaredi* from the state of Maranhão. Until now, the distribution of the species was known only from the type locality and surroundings in the Planalto Ibiapaba and isolated populations in Rio Grande do Norte state. We extend the distribution of *P. jaredi* about 610 km southwestward from Serra das Flores, municipality of Viçosa do Ceará, state of Ceará (Andrade et al. 2016). Our record is further west and south than any previously known occurrences of this species (Figure 3). The dorsal color of *P. jaredi* varies from gray to brown, with dark gray or dark brown irregular spots (Andrade et al. 2016). However, we notice a previously unnoticed variation in pigmentation, with individuals showing a greenish color, with irregular spots, variably gray to dark green, on the back and legs.

The Parque Estadual do Mirador is located in a poorly studied region in one of the best-preserved Cerrado areas in northern Brazil, which has high biodiversity (Barreto 2007; Brasileiro et al. 2008). Recently, two other species (*Adenomera saci* and *Leptodactylus sertanejo*) have had their geographical range increased to include the park (Araújo et al. 2015; Lima et al. 2015). Thus, these new records reveal the importance of conducting more inventories of fauna, especially amphibians, in northeastern Brazil; they also reinforce the important role the park has in the conservation of the amphibian fauna of Maranhão state.

ACKNOWLEDGEMENTS

We thank Felipe Silva de Andrade for confirmation of the species identity and for very useful comments on the manuscript, Vinícius Dias de Carvalho for English review, the Secretaria de Estado de Meio Ambiente e Recursos Naturais-SEMA for the collection permit (license number

008/2013) and to Universidade Federal do Piauí-UFPI, Campus de Parnaíba, for logistical support for collections. Financial support was provided by Fundação de Amparo à Pesquisa do Estado do Maranhão (FAPEMA) through the Support Program Research Projects UNIVERSAL, edital n° 001/2013– FAPEMA and by grants of doctorate degree (BD-01163/13).

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Authors' contributions: EBA, TGPL and KCA collected the data; EBA and LNW identified the specimens; EBA, TGPL and KCA wrote the text; EBA made the analysis, and JRSAL and LNW reviewed and corrected the text.

Received: 28 June 2016
Accepted: 17 December 2016
Academic editor: Tiago Vasconcelos